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Erratum

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MODELING AND RESEARCH OF CIRCUITSOF INTELLIGENT SENSORS AND MEASUREMENT SYSTEMSWITH DISTRIBUTED PARAMETERS AND VALUES

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Abstract: *transforming circuits of intelligence transducer, current sensors - transducers, research input and output signals of intelligent sensors and measurement systems*

Key words: *electromagnet transducers, transformation, converting, electrical signal, activity-transform, active magnetic resistance, magnetic material, sensitive element, interchain coupling coefficient.*

Introduction

The primary transducers with distributed parameters of intelligent sensors and measurement systems with various value and parameters (magnetic core, air gaps, electrically conductive materials, dielectrics - as an insulating plate, etc.) have a complex geometrical configuration and structure. Taking this as needed information, as well as concentrated and distributed character (nonsymmetrical and nonlinear properties) of transforming area and three-dimensionality of volume of signal from intelligent sensors and measurement systems (current and voltage) of electrical circuit, is clear that calculating them in full a difficult task even with the use of the most powerful modern computers. In given thesis carried out modeling and investigation of the transformation chain, splitting them into separate components and fairly simple elementary regions based on replacing it with a three-dimensional electric circuit of substitution - a graph model of signal circuits of intelligent sensors and measurement systems[1,2].

Main part

The research focused on stage of analysis and synthesis of elements' constructions on basis of topological graph representation of principles of transformation, including concentrated and distributed quantities and parameters of various physical nature as intelligent sensors and measurement systems. The solution of problem of analyzing and synthesizing principles of operation of intelligent sensors and measurement systems of transducers of current and voltage converters in graph models is reduced to the procedure for converting the initial graph consisting of the branches coming from the node, the primary electric current of incoming $I_{Э1}$ - primary current to $U_{Э2}$-secondary voltage is the output electrical signal.

Each node of the graph model characterizes some value that participates in the process of work - the transformation of electromagnetic current and voltage converters, and the branches reflect the nature of the functional relationship between the values and parameters of the transformation elements. The great variety of design of the circuits for converting electromagnetic current and voltage converters, the number of which continuously increases as new physic technical effects are used in them, raises the problem of their systematization and selection of optimal quantities and parameters of the transformation and circuit that meets the requirements of a modern automatic control and management system. Solving this problem requires, in turn, preliminary consideration of at least three tasks [3,4].

Classical methods for calculating the circuits of the transformation of intelligent sensors and measurement systems of current and voltages of labors converters, are very approximate and do not always allow for the peculiarities of transforming of signal from transducers[4].

Some methods of calculating, with used of computer technology, although they provide sufficient accuracy of results, allow to take into account the influence of various factors, the properties of materials, etc., but are complicated by a large amount of computation. Therefore, it seems more expedient to improve computational methods of calculation, in particular, mathematical models of current-to-voltage conversion based on magnetic conversion circuits [2-4].

Based on the magnetic circuits of the transformation of intelligent sensors and measurement systems of current and voltages with lumped or distributed parameters, the algorithm for constructing the model of the transformation elements - the magnetic system - is explained, since the structure, shape and geometric dimensions, as well as magnetic materials of the magnetic system, reflect the essence of the magnetic circuits of the transformation of electromagnetic current and voltage transducers .

Under the elementary sections of transformation circuits of electromagnetic current and voltages converters with longitudinally distributed parameters, means such transformation elements, in which magnetic parameters $R1_\mu = \dfrac{l}{\mu S}$ are distributed in a direction parallel to centerline of magnetic circuit (here and after index μ denotes magnetic character of parameter or value). The magnetic sections of circuit for conversion of electromagnetic current and voltages transducers with transversely distributed parameters will be understood as those elements in which transverse magnetic parameters $R1_\mu = \dfrac{l}{\mu S}$ are distributed in a direction transducers to axial line of magnetic circuit [4, 6].

Let us consider in more detail the features of calculating the magnetic circuit of a transformation with an air gap and investigate the laws of the distribution of magnetic fluxes - Φ_μ, magneto moving force (m.m.f.) - F_μ in them, using the generalized model as an example, several variants in the form of sections of a magnetic circuit with transversely, longitudinally and vertically distributed parameters and magnitudes.

The real physical transformation circuit of current and voltage transducers, is replaced by an equivalent model with longitudinally, transversely and vertically distributed parameters or a model, represented in three-dimensional coordinate system (i, j, k). The parameters and values of model are determined on the basis of geometric dimensions and taking into account unit-specific distributed parameters of intelligent sensors and measurement systems.

Then resistances of elementary sections of equivalent model of transformation chain are determined from equations [2,4]:

$$R_{\mu\ i,j,k} = R_{\mu\ i,j,k}\,\Delta X_i\,, \qquad (1)$$

$$\Pi 0_{\mu\, i,j,k} = \Pi_{\mu i,j,k}\Delta X0_j\,, \qquad (2)$$

$$\Pi 1_{\mu\, i,j,k} = \Pi_{\mu i,j,k}\Delta X1_k\,, \qquad (3)$$

where: $\Delta X_i = X/N, \Delta X0_j = X0/M$,

$\Delta X1_k = X1/K$ - elementary parts of the space partition;

$X, X0, X1$ - length of transformation sites;

X - longitudinal length of sections of transformation;

$X0$ - vertical length of sections of sites;

X1 - transverse length of transformation sites;

N, M, L – number of dividing sections.

The algorithm of constructing a model of circuit of intelligent sensors and measurement systems of current and voltage is represented in following steps:

1. Complex circuit of the transformation of intelligent sensors and measurement systems will be divided to elementary parts (taking into account

magnetic circuit, air gaps, additional cores, and scattering fluxes) according to principle of magnetic flux constant at each section of conversion chain.

2. The preliminary distribution of the m.m.f. and magnetic flux along sections of conversion circuit defined.

For example: a preliminary distribution of magnetic induction in sections *i* and *j*, where there is an air gap is defined as follows:

$$B_{i,j} = \frac{\Phi_{i,j} \Pi 0_{\mu\, i,j}}{\delta_{i,j}}, \quad (4)$$

where $\Phi_{i,j}$- magnetic fluxes in sections of transformation chain;

$\Pi_{\mu\, i,j}$ and $\Pi 0_{\mu\, i,j}$ are magnetic conductivities of *i* and *j*-th sections of conversion circuit.

If current flowing through current lead - primary winding of electromagnetic current and voltage transducers $I_{\text{эвх}}$ is set, then m.m.f. in magnetic conversion system is defined as follows:

$$F_{i,j} = I_{\text{эвх}} w_{\text{ов}}, \quad (5)$$

where: $w_{\text{ов}}$ - number of turns of current conductor - field winding.

Given magnetizing force of coil and presence of air gaps, magnetic flux is determined as follows:

$$\Phi_{i,j} = \Pi 0_{\mu\, i,j} (F_{i,j} - F_{i,j+1}). \quad (6)$$

3. The complex conductivity of each longitudinal *i*, *j*-th section will defined as:

$$\Pi 0_{\mu\, i,j} = Y_{\mu\, i,j} = Z^{-1}_{\mu\, i,j} = g_{\mu\, i,j} - jb_{\mu\, i,j}, \quad (7)$$

where $Z_{\mu\, i,j} = R_{\mu\, i,j} + jX_{\mu\, i,j}$ is complex magnetic resistance of *i*, *j*-th section.

4. For the considered magnetic section of conversion circuit: $R_{\mu\, i,j} = \rho l_{\mu\, i,j} / F_{i,j}$ - active magnetic resistance – parameter of *i*, *j*-th section, characterizing property of magnetization of magnetic material under influence of applied force; $X_{\mu\, i,j} = \rho l_{\mu\, i,j} / S_{i,j}$ - reactive magnetic resistance of *i*, *j*-th section, characterizing loss of magnetizing force on eddy currents and hysteresis; $\rho R_{\mu\, i,j}$ and $\rho X_{\mu\, i,j}$ respectively, specific reactive and reactive magnetic resistances of *i*, *j*-th section of magnetic circuit, determined depending on magnetic induction and magnetic characteristics; length of *i*, *j*-th section of magnetic circuit of transformation.

If *i*, *j*-th segment of circuit is an air gap (in which the sensing element is installed in gap (a flat measuring winding, a Hall sensor, etc.) and buckling can be neglected), then we determine its active magnetic conductivity

$$\Pi 0_{\mu\, i,j} = R^{-1}_{\mu\, i,j} = \sqrt{2}\mu_0 \frac{F_{i,j,k}}{\delta_{i,j}}, \quad (8)$$

where; *i*, *j* - parts of magnetic circuit; is magnetic constant of air. If *i*, *j*-th segment is a scattering section, then determine magnetic conductivity of scattering:

$$\Pi 0_{\text{p}\, i,j} = g_{\mu} l_{\mu\, \text{p}\, i,j}, \quad (9)$$

where specific magnetic conductivity of the scattering, obtained from structure and analytically from known relationships.

5. The field of graph of designated nodal points will taking put into account their mutual arrangement.

6. Connection each pair of node points (without taking into account scattering areas) graph constructions between each other by two oppositely directed arcs according to designated nodes of initial design of transformation circuits of electromagnetic current and voltage transducers.

7. For each arc of obtained nodal subgraphs, will assigned a complex transfer equal to ratio of complex conductivity of elementary region between nodes of initial system under consideration to complex conductivity of node to which arc of graph is directed as:

$$T_{i,j,k} = \frac{\Pi 0_{\sum i,j}}{\Pi_{\sum i,j} + \Pi 0_{\sum i,j}}. \quad (10)$$

8. The field of graph points corresponding to given quantities (primary electric current) and these points will be considered as nodes of graph model of transformation circuit We put on.

9. Connection nodes $F_{i,j}$ with arcs corresponding to complex materials of nodes of section on which source will be located in form of model.

For construction a three-dimensional graph model of sections of transformation chain, considered their main elements, determine as analogous values of action $(U_{i,j,k})$, reaction $(I_{i,j,k})$ and charge $(Q_{i,j,k})$, as well as a parameters: resistance $(R_{i,j,k})$, capacitance $(C_{i,j,k})$ and inductance $(L_{i,j,k})$ place in current transducers to voltage.

When drawing up a generalized transformation graph model of intelligent sensors and measurement systems, following assumptions are are will made:

- the transformation element of intelligent sensors and measurement systems is divided into *i*, *j*, *k* elementary sections of length *ΔX*, which in general case depends on conditions of a given accuracy and stability of solution of problem;
- the parameters of intelligent sensors and measurement systems with limited of section *ΔX* are considered to be uniformly distributed. The changes in the parameters can occur abruptly at boundary of fission sites;
- sources of flows, and m.m.f. node, and are taken into account by inclusion in corresponding node points.

On the bases on formed algorithm for constructing a transformation, will construct a generalized graph model for sections of transformation circuit of intelligent sensors and measurement systems current and voltage. In case, when nodes of connecting influencing quantities - fluxes. through coefficients of relationships between values of electric, magnetic and thermal, and so on. physical nature, for this cases communication means as a parameters between magnetic flux and m.m.f. of circuit of intelligent sensors and measurement systems.

The circuit of transformation of electromagnetic transducers of primary current to secondary voltage consists sections of transformation - volume space with longitudinally, transversely and vertically distributed magnetic parameters, which determining on basis of corresponding calculations and initial data: a source - a current of a feed, geometrical sizes, quantity of elementary horizontal, longitudinal and vertical sections of separation, material of magnetic circuit and sensing element (secondary winding, sensor, etc.).

The m.m.f. are defined as follows: for model node $F_{\mu 11}$ is determined on basis of the interchain coupling coefficient between electric and magnetic circuits. The input signal at point $F_{\mu 11}$will determined fron next equal:

The input signal at the point $F_{\mu 11} = K_{IF} I_Э$;

$$\frac{F_{\mu 11} - F_{\mu 12}}{R_{\mu 11} + R1_{\mu 11}} = 0 \tag{11}$$

$$F_{\mu 11} = F_{\mu 12} \tag{12}$$

$$\frac{F_{\mu 11} - F_{\mu 12}}{R_{\mu 11}} - F_{\mu 12} \cdot G_1 = 0 \tag{13}$$

$$F_{\mu 11} - F_{\mu 12} - F_{\mu 12} \cdot G_1 \cdot R_{\mu 11} = 0 \tag{14}$$

$$F_{\mu 12} = \frac{F_{\mu 12}}{1 + G_1 \cdot R_{\mu 11}} \tag{15}$$

where $R_{\mu 11} = \dfrac{l}{\mu \cdot \mu_0 \cdot a \cdot b}$; $G_1 = \dfrac{\mu_0 \cdot a \cdot b}{l_{в.з}}$ are the resistance and conductivity of the sections of the transformation circuits.

The mathematical form of model will have next form:

$$\begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} & A_{15} & A_{16} \\ A_{21} & A_{22} & A_{23} & A_{24} & A_{25} & A_{26} \\ A_{31} & A_{32} & A_{33} & A_{34} & A_{35} & A_{36} \\ A_{41} & A_{42} & A_{43} & A_{44} & A_{45} & A_{46} \\ A_{51} & A_{52} & A_{53} & A_{54} & A_{55} & A_{56} \\ A_{61} & A_{62} & A_{63} & A_{64} & A_{65} & A_{66} \end{bmatrix} \times \begin{bmatrix} F_{\mu 11} \\ F_{\mu 12} \\ F_{\mu 13} \\ F_{\mu 14} \\ F_{\mu 15} \\ F_{\mu 16} \end{bmatrix} = \begin{bmatrix} F_{\mu 10} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{16}$$

For the parameters: *l = 0,04 m, a = b = 0,04 m, μ = 4000 HN / m, μ0 = 1,25 * 10-6 HN / m*, the following values of nodal m.m.f. were obtained:

$$R_{\mu 1} = R_{\mu 2} = R_{\mu 3} = R_{\mu 4} = R_{\mu 5} = R_{\mu 6} = R_{\mu} =$$

$$= \frac{l}{\mu \cdot \mu_0 \cdot a \cdot b} = \frac{0.02}{4000 \cdot 0.04 \cdot 0.04 \cdot 1.25 \cdot 10^{-6}} = 2500\ Ом$$

$$G_{\mu 1} = G_{\mu 2} = G_{\mu 3} = G_{\mu 4} = G_{\mu 5} = G_{\mu 6} = G_{\mu} =$$

$$= \frac{\mu_0 \cdot b \cdot l_{в.з}}{\delta_{в.з}} = \frac{1.25 \cdot 10^{-6} \cdot 0.04 \cdot 0.02}{0.005} = 0{,}0000002\ Ом$$

$$U_{\mu 0} = K_{IF} \cdot I_{эвх} = 100 Ав; U_{\mu 1} = 99.7 Ав;$$
$$U_{\mu 2} = 99.45 Ав;$$
$$U_{\mu 3} = 99.25 Ав; U_{\mu 4} = 99.1 Ав; U_{\mu 5} = 99.0 Ав;$$
$$U_{\mu 6} = 98.95 Ав.$$

In fig.1given the graphs of change flux and m.m.f. on longitudinal sections of transformation signal of circuit of intelligent sensors and measurement systems

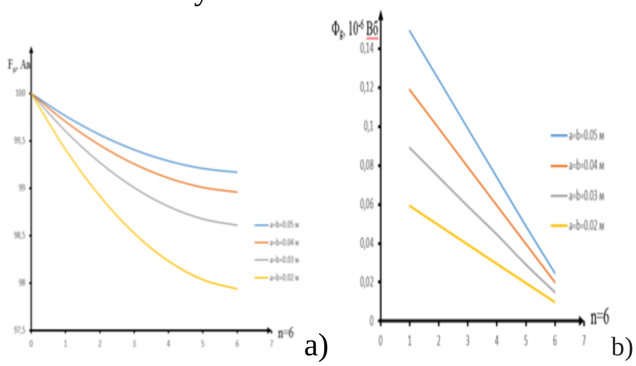

Fig. ***The graphs of change flux and m.m.f. on longitudinal sections of transformation signal of circuit of intelligent sensors and measurement systems where:***
a – graph of changing of m.m.f.and b –graph of changing of flux

Conclusion

1. Motivated, that using flat measuring windings in intelligent sensors and measurement systems of primary current to secondary voltage as detector element, provides reception unified out signal with parameter: voltage - *20* V, current - *100 mA* and allows develop new in electromagnetic transducer of current to voltage with flat measuring windings, being up to quality combined control system of power of energy systems.
2. Installed, that value out voltages U_{eout} depends on degree of perpendicular and uniformities of crossing magnetic flow area flat measuring windings, optimal resistances and conductivities complex portioned area and structures of magnetic system of intelligent sensors and measurement systems of current to voltage.
3. Accounting entropy inaccuracy of intelligent sensors and measurement systems of the current to voltage does not exceed *0,2%*, but experimental importance of inaccuracy electromagnetic transducer of current to voltage with flat measuring windings forms *0,21%*.
4. Determined, that total reliability combined control system source of electrical power of power systems on the base of intelligent sensors and measurement systems of current to voltage with flat measuring windings forms, best value equal to *0,96*.
5. Employed intelligent sensors and measurement systems during transforming of current to voltage in electric nets of systems of power supply more than 20 enterprises shows of accuracy and automations of control source of reactive power, have allowed to reduce the loss to electric powers on 11,26% under normative importance 13,29% of account due to increasing of the class of accuracy of elements control system of reactive power of the power systems from 1,0 to 0,5.

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